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Shaft Mucking Investigation PART 1

Jorge R. Delzo

Mining 68

Mining Engineering

A Thesis

Submitted to

Professor K. S. Stout

SHAFT MUCKING INVESTIGATION

by

Jorge R. Delzo

May 10, 1957

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Residence Hall
Mont. School of Mines
Butte, Montana
January 18, 1957.

Mr. Koehler S. Stout
Mining Department
Mont. School of Mines
Butte, Montana

Dear Mr. Stout:

In compliance with your instructions received on Sept. 27, 1956, I hereby respectfully submit the first part of my Thesis on Shaft Mucking, as partial fulfillment for my degree of Bachelor of Science in Mining Engineering.

The first paper of my Thesis covers methods and practices used in Mucking Inclined Shafts; the second paper will cover the same operations, but on Vertical Shafts.

I earnestly hope, the information gathered on this report will be helpful on further research on this important phase of Mining, which could either result on an improvement of today-shaft mucking machines and methods, or bring forth new ideas or future designs, toward the end of solving one of the mining's biggest problems, shaft mucking.

Very Truly Yours,

Jorge R. Delzo

Jorge R. Delzo

ABSTRACT

In Mining, as in other industries, the march of time and progress has had its effects. In doing so it has almost complete changed methods and practices used by our ancestors in every mining operation.

The main reason why mine management has turned to machines in the development of mines, is to meet the always increasing demand for metals and the rising cost of labor.

In one of the mining operations, Shaft Sinking, Mucking is usually the most time-consuming operation. This is especially true, because this operation represents the largest fraction in cost and time in any shaft-sinking problem. For these reasons, it is, then, the most logical phase in mining operations for the introduction of cheaper methods.

This paper represents an attempt to explain the operation of inclined-shaft mucking, and machines developed for this purpose. It also covers some research done for the design of a continuous shaft mucking device, which could in the future prove to be the answer to this important problem. In many small or intermediate mining operations, where this problem has been a prime headache, the added costs of shaft mucking, because of lack of speed, and versatility, might very well mean the difference between profit and collapse.

Report on

INCLINED-SHAFT MUCKING

PURPOSE OF THIS REPORT

This investigation represents part of my Thesis, which I submit as partial fulfillment for the degree of Bachelor of Science in Mining Engineering.

Throughout the engineering industry, report writing plays an important role. Therefore, the accomplishment of this paper, will undoubtedly help me to get better acquainted on this type of skill.

SECTION I. MUCKING METHODS

A. Hand Mucking. The operation of hand mucking in inclined shafts can be performed on buckets if the inclination is steep. These buckets may either run on skids or on a trolley. Fig. 1. For flat inclinations, skips or cars running on rails are used; the lowest end of this track capable of being raised on blasting, reaches from end of timbering to shaft bottom.

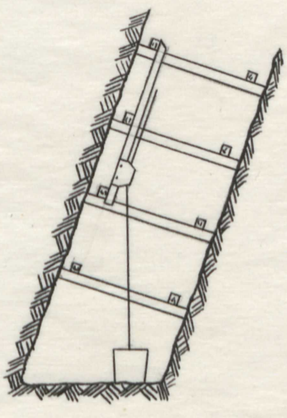

Fig. 1. Bucket and trolley used for mucking incl. shafts.

Hand shoveling loads 9-13 ft^3. per man-hour, depending on character of muck, conditions at shaft bottom and promptness of hoisting service. Shoveling in a shaft bottom is difficult, though when 2 ends are blasted alternately, it is facilitated by laying steel plates to receive the muck in the end not blasted.

B. Mechanical Mucking. Although hand mucking is still practiced in some mines, emphasis has been put on the development of mechanical devices, which has result in a greater speed and reduced costs of shaft mucking.

It is desirable that a shaft mucker meet the following requirements:

a. Be compact, so that it can be transported in a shaft compartment without being disassembled.

b. Use a minimun of man power to operate.

c. Utilize a simple control system.

d. Provide a maximun of safety.

e. Be designed so that it can muck a complete shaft with one set up.

f. Reduce the mucking time.

g. Be cheap and simple to build and economical to operate.

1. Mechanical Mucking as Practiced in the Chief Consolidated Mining Co. A 12-degrees incline was started on this mine, mucking being done by hand. Later on steepened to a pitch of 23°, and as an experiment it was agreed to try a standard Eimco-Finlay

model 12 B mucking machine in conjunction with a car of approximately 75 ft^3. of capacity, as shown in Fig. 2. Despite the fact that experienced operators ran the mucking machines, there were several serious drawbacks to this operation. In the first place, the traction of the machine on the 12-lb. rail which was being used was not sufficient to support the weight of the operator on the stand along with a load of muck; consequently a tall man was needed who could stand in one place and stretch forward when loading the bucket, and bend backward when emptying it. The mine car was held in place on the incline by the cable with which it was lowered by the tugger at the collar of the winze; so the mucker did not have to handle the weight of the car. Secondly, the lighter machine it was being used had a tendency to tip forward as the load was being picked up and this necessitated placing a heavy weight on the back of the machine. The third and most serious drawback was the danger of the machine losing all traction and slipping down to the face.

The positive control device for solving drawbacks previously mentioned, in mucking inclines by the use of mucking machines, essentially consists of drums attached to the front wheels of the machine on which are wound cables attached to spikes driven in the ground in back of the machine. Fig. 3. To throw the center of gravity back far enough the cables from the drums are run over idler pullies attached to the back axles and the down pull on the cables is achieved by pushing a bar under the track and over the

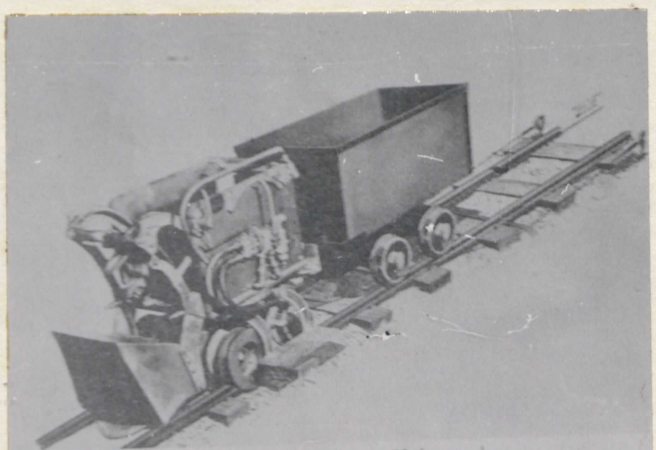

Fig 2. This equipment was used on a 23-degree slope

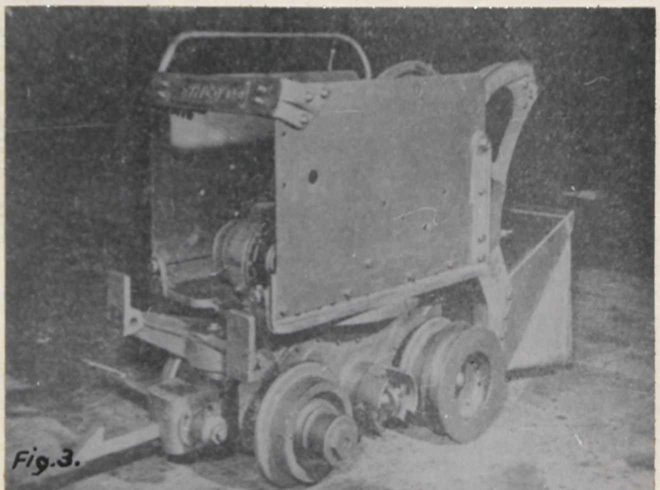

Fig.3.

The lighter mucking machine uses an idler drum on the rear wheels to preven[t] upsetting when the dipper is loaded cables approximately 6 ft. in back of the machine. Normally, during the course of mucking up a round this bar has to be brought forward several times, but the spikes only have to be moved when the drums have run out of cable.

An Eimco 21 mucker was used in driving an incline at an angle of 18 degrees for 300 ft. without special attachment. Apparently there was not trouble in mucking out 50 two-ton cars in less than a shift, and it was not necessary to weight the back of the machine. The success of this operation was probably due to the fact that the Model 21 mucker is much heavier; a wider gage track and a 40-lb. rail was used, which result in a much better traction.

The use of this loader presents the problem of getting the muck from the working face. The adaptation of the rocker-shovel has speeded up face advance many times and has also made it possible to complete all allied operations as the face advances.

On the 12-degrees incline, mucking by hand, thirteen shifts worked brought the following results:

Total tons, 48; which means an average of 3.69 ton/shift.

		Per ton.
Labor	$ 323.47	$ 6.739
Air power	33.61	0.70
Supplies	22.79	0.475
	$ 379.87	$ 7.914

On the 23° incline, mucking by mechanical muckers, thirteen shifts worked brought the following results:

		Per ton.
Labor	$ 779.73	$ 3.878
Air power	140.52	0.70
Supplies	95.45	0.475
	$ 1,015.70	$ 5.053

The obvious conclusion to be drawn is that mechanical mucking in inclines, whether figured on a footage or per ton basis, cuts the cost of the operation at least two-thirds over hand mucking.

2. <u>Mechanical Mucking as Practiced in the Ophir Mine, Utah</u>. In this mine two mucking machines were successfully used in the face at the bottom of a two-compartment 26° incline shaft.

In converting the two loading machines to shaft muckers, the following changes in design were made:

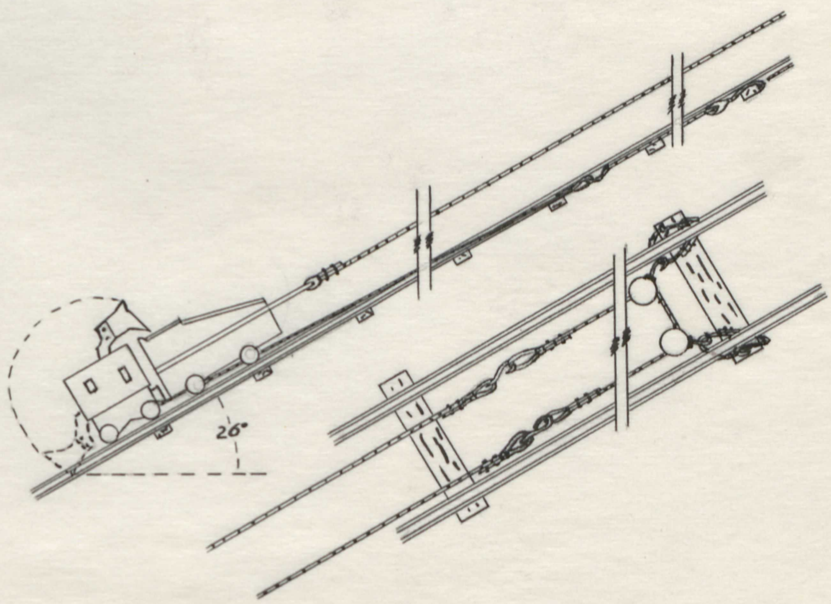

Fig. 4. Schematic arrangement for mucking inclines, used in the Ophir Mine.

a. The cable drum was mounted on the inside rather than the outside of the rear wheels to provide sufficient room for both loaders.

b. A steeper discharge angle on the bucket and 4 in. were added to the discharge lip.

c. The rocker arms were extended an inch from the frame to permit the bucket to swing freely to both sides on a wider-than-usual arc.

d. A 200-lb. counterweight was attached to the rear of the machine, to increase the machine's stability for digging in the muck pile.

To anchor the loaders when in use, a double wrap of 3/8-in. cable was made around two adjacent track ties so that the ends loops fell inside the rails (two clamps kept the cable from slipping). Two snatch blocks for each loader were hooked in the end loops and a 5/8-in. equalizing cable drum through the blocks. These cables were 48 ft. long, although shorter lengths were available. The anchor cables were spaced at 40-ft. intervals. The 60-ft. drum cables of the loader were fastened to the equalizing cables by means of safety hooks. Fig. 4, shows a schematic arrangement of the cable anchorage for mucking.

Loading speed was determined largely by the fragmentation. In moderately fine muck, a 34 ft^3. skip could be loaded in as little as 1½ min. During a mucking cycle, an average of 10 to 12 skips was loaded each hour. However, time used in breaking

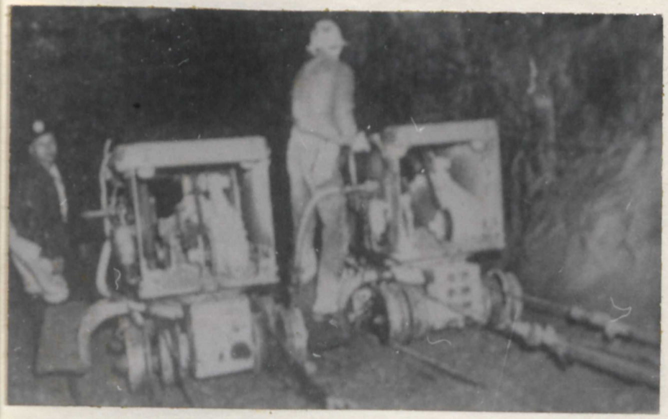

Fig. 5. Mucking machines at bottom of inclined shaft.

Fig. 6. Mucking in the shaft.

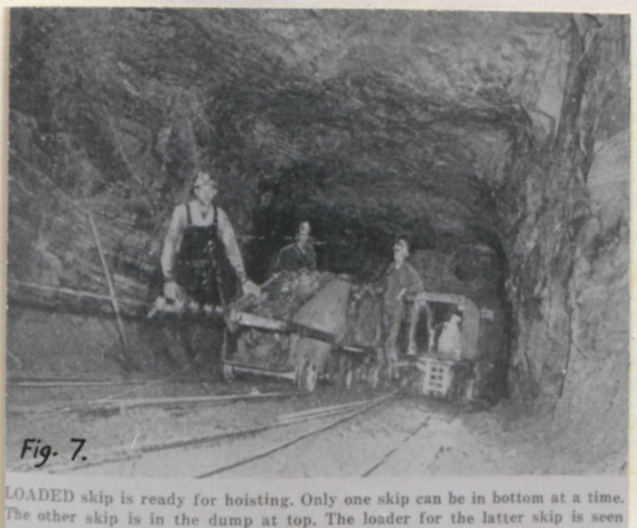

Fig. 7.

LOADED skip is ready for hoisting. Only one skip can be in bottom at a time. The other skip is in the dump at top. The loader for the latter skip is seen at the right of the heading.

Fig. 8.

DRILL JUMBO is in position for drilling at face in bottom of incline, after removal of two loaders to 1200 level station.

boulders, laying ties, and waiting for skips reduced the number of skips which could be loaded during the shift. Cleaning and trimming the face required one hour of the mucking cycle, and part of the last skipful was hand-mucking.

Dual Mucking Machines were also used for a short time on grades as steep as 30 degrees, but their performance was not satisfactory.

3. <u>New Mechanical Mucking Device Used For Mucking Bunker's Hill Auxiliary Incline Shaft</u>. In this shaft, a three-compartment incline shaft, a new machine designed and built at the Bunker Hill Mine, Idaho, was put into practice for mucking purposes. Two of this new type of muckers were used, operating in balance in the shaft, which was sunk at a 50° angle.

This new mucker, shown in Fig. 9, is heavy and sturdy and is mounted on wheels so that it can be hoisted from the bottom of the incline to the dumping point in the footwall of the shaft, from where it is transferred by slushing to the main shaft.

This machine consists of four main parts: a truck, the main frame, the boom, and the bucket. The latter can be rotated through a 180-degree arc.

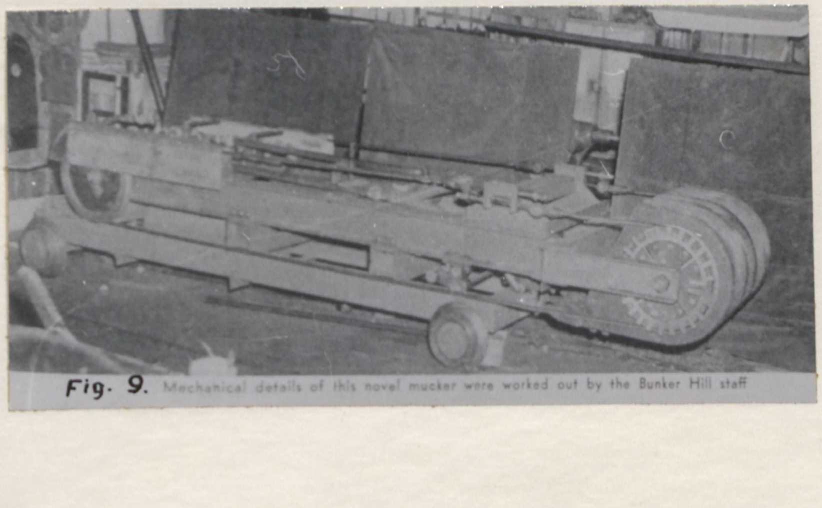

Fig. 9. Mechanical details of this novel mucker were worked out by the Bunker Hill staff

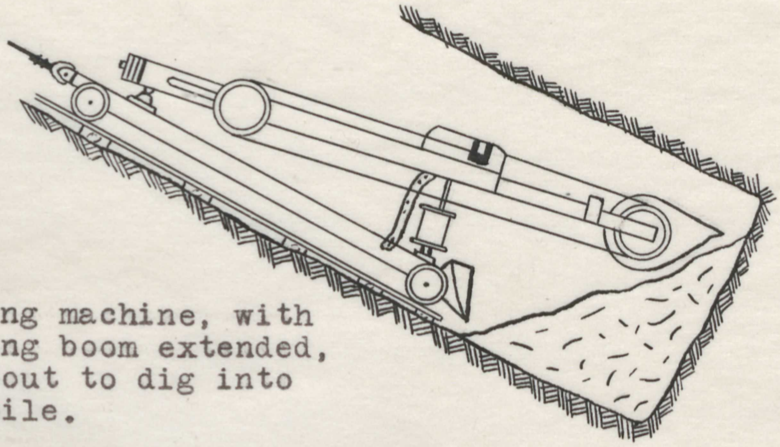

Fig. 10. Mucking machine, with sliding boom extended, is about to dig into muckpile.

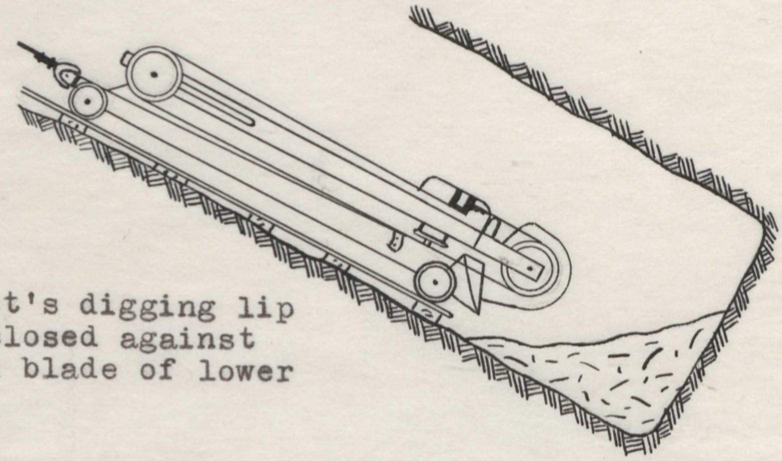

Fig 11. Bucket's digging lip has closed against steel blade of lower deck.

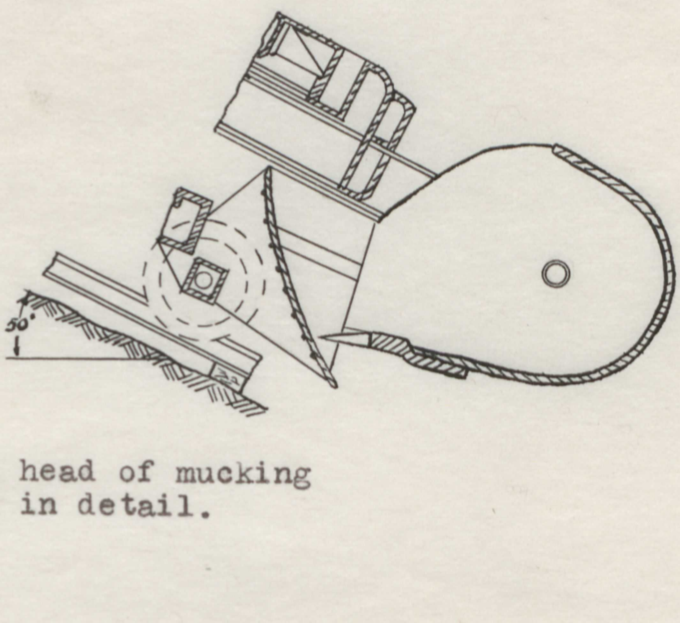

Fig. 12. Digging head of mucking machine in detail.

The operation of the machine is illustrated in Figs: 10, 11, and 12, and is as follows: The machine is lowered to the muckpile at the bottom, with its bucket open, by a hoist installed at the shaft collar. When it reaches the bottom, an air hose is attached to operate the motor, and the machine is lowered to rest with its full weight on the muckpile. The motor is then started in such a direction that the screw retracts the sliding boom. As this is drawn back, the bucket rotates and, owing to the weight of the mucker, bites gradually into the muckpile. As the bucket completes its turn, it forces the broken rock against the steel blade that fits against the bucket's digging lip in a manner similar to the operation of a clamshell. After this bite has been taken into the muckpile, the air hose is disconnected and the machine with its load is hoisted to the dumping point. Here, another air hose is connected and the motor is run in the reverse direction. This forces the sliding boom forward, causes the bucket to rotate to open position so that the broken rock falls into a raise that has been holed through under the footwall track. The machine is then lowered to the bottom of the incline for the next load.

Each load amounts to slightly more than 1/3 yd^3. By operating two of these machines in balance, one on each hoisting compartment, a load was delivered at the dumping point every two minutes. At this rate the two machines mucked at a rate of about 10 yd^3. per hour.

Although it was designed especially for mucking the 50°-inclined Auxiliary Shaft, the Bunker Hill shaft mucker, with minor modifications, will muck an inclined shaft of any degree.

4. Dragline Bucket Principle. A three-compartment, 52°-incline auxiliary shaft was sunk on the northward extension in depth of the Sterling Orebody, property of the Sterling Mine, New Jersey.

When considering the mucking phase of the sinking operation, hand shoveling was rejected as undesirable, because of the cost, time involved and the disinclination of current labor to perform arduous work. The 52° pitch of the shaft ruled out any application of scraper and slide loading directly to a skip, while the limited shaft dimensions made difficult the use of scraper and loading pan or bucket. Consideration was given to an inclined shaft mucker embodying the principle of an undercutting shovel bucket, and to a recent publicized machine with a bucket operating in a manner similar to a clamshell. In the operation of these muckers it was felt that the necessity for hoisting each bucketful to the dumping point through a distance of over 1,000 ft., or intermediate muck transfer, was a definite disadvantage. Another deterrent was the fact that the small amount of sinking involved did not warrant the purchase or fabrication of such equipment.

The mucking method that was used was one of a dragline principle.

A toothed lip bucket of a capacity of 13 ft^3., open at the front end was designed and constructed, having pull and tail ropes hooked at either end. The bucket is hoisted through a stationary sheave located at the front. The only alteration required to the original design was a counterweight added to the rear to prevent overturning.

A 20-ft. long sinking cage, as shown in Fig.13, was constructed, and consisted of a wheeled chasis containing three built-in steel platforms. Three air driven hoists were mounted on the platforms; a single drum at the upper and lower platforms and a double drum at the center.

In the mucking operation, one or two passes were sufficient to fill the bucket, fig. 14. The pull and tail ropes are disconnected by means of open hook attachments, and the upper single drum hoist raises the bucket to the dumping position. The cable from the lower hoist, passing through one of the overhead blocks, is then hooked to the rear of the bucket, while a fixed chain, suspended over the skip, is attached to the bail. With proper manipulation by the operators of the upper and lower hoists, the lip of the bucket is lowered to rest on the edge of the skip, as shown in Fig. 15, the bottom is then raised and the muck dumped into the skip.

From every set-up up to three or four shaft rounds could be mucked before bucket hoisting distance became excessive.

Fig. 13. Sinking cage, consisting of wheeled chasis.

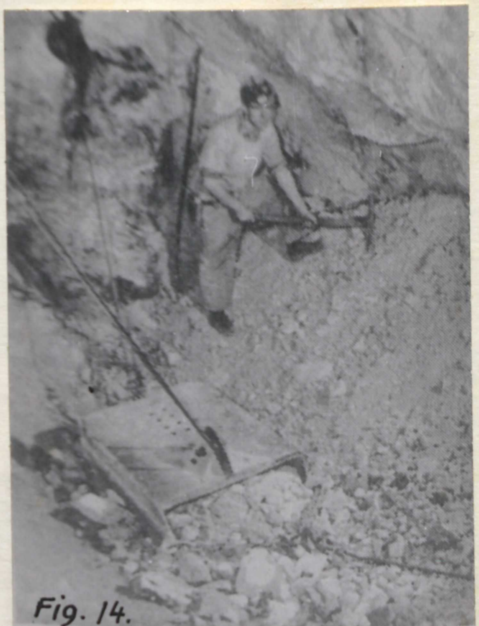

Fig. 14.

Scraping along the muck pile, the bucket picks up its load

Fig. 15. Dumping operation.

By the above method, the average advance per shift was 1.97 ft. In the mucking cycle four buckets were required to fill each trip and in one 7-hr. shift a record of 2,200 ft^3. of rock was mucked, or one skip every 9 minutes. Four men were sufficient to handle this mucking arrangement.

5. Use of Scrapers for Mucking Incline Shafts. Scrapers are generally used for mucking inclines of a rather shallow slope.

a. Method used in Pend Oreille Mine. On the mineralized area of the east bank of the Pend Oreille Mines and Metals Co., a 1,600 ft., 17°-inclined shaft was sunk.

Scrapers were used to remove the muck from the face of the incline to the surface during sinking. As sketched in Fig. 16, a 15-hp. motor scraped ore back from the face. Then it was picked up by two scrapers in tandem placed 15 to 300 ft. apart

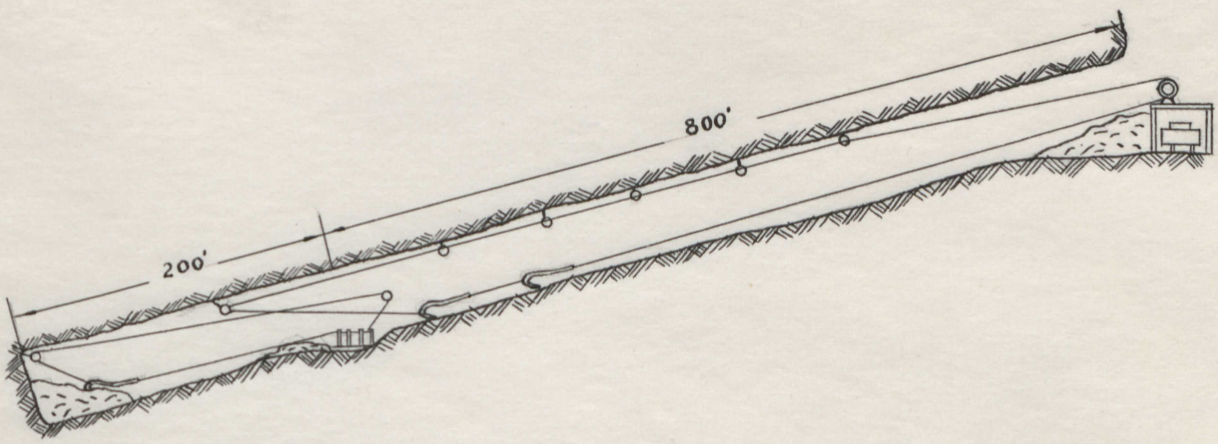

Fig. 16. Use of Scrapers in Pend Oreille Mine.

for 867 ft. of sinking. They moved a load of about 1/2 tons. As the drum of the 50-hp. hoist could accomodate only 600 ft. of 3/4-in. cable, slushing was done in two steps. A section of portable cable 200 ft. long was inserted in the pull-line, increasing the distance between the hoist and scraper to 800 ft. Broken material was scraped part way, then the 200-ft. section of portable cable was removed, and the muck was scraped up to the surface.

b. Method used at Michigan copper country. In the copper country of the Upper Peninsula, the ore bodies dip 32° to 45°. Inclined shaft mucking is done as shown in Fig. 17, by using a

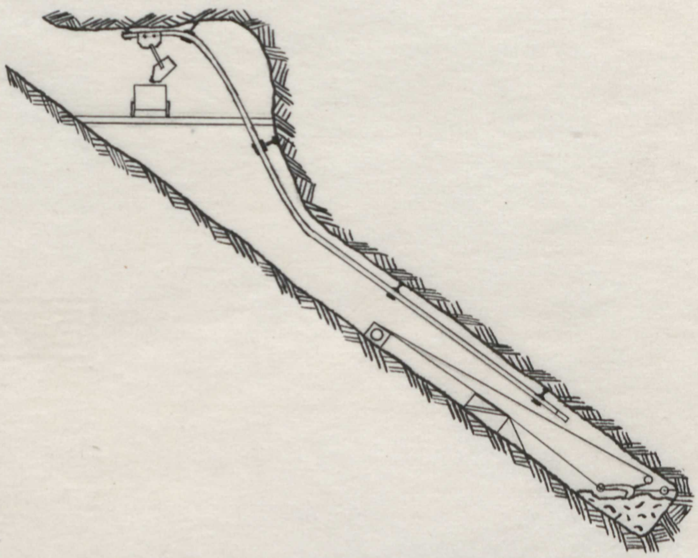

Fig. 17. Set up used in Michigan copper country.

beam monorail, a scraper ramp, a slusher hoist, and a bucket which dumps into a car at the station.

The operation in simple terms consists in slushing to the box behind the inclined ramp. When this box is filled, the bucket on the monorail is positioned near the scraper, and an air cylinder raises the scraper pocket and dumps it into the bucket. The monorail is then pulled up to the transfer point.

c. Method used in Fisher Hill. In deepening its 33°30'-inclined shaft, the Republic Steel Corporation, mucked the broken rock by slushing with a scraper and slide.

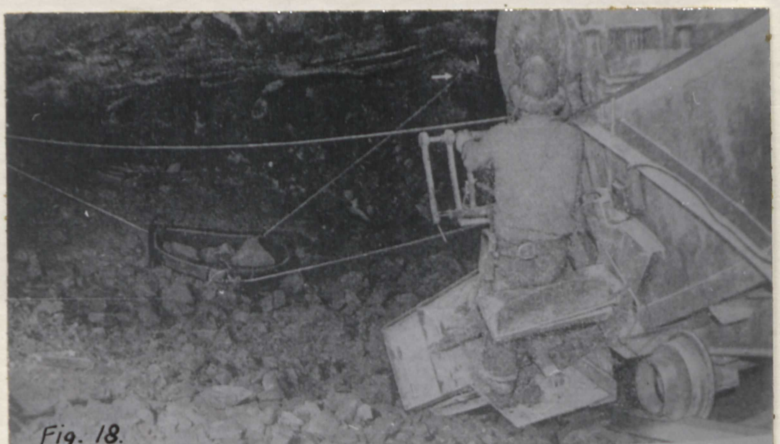

Fig. 18.

THREE-DRUM TUGGER HOIST is mounted on the slide. The scraper is starting to pick up its load of broken rock in the shaft bottom. The arrangement of the snatch blocks in the face is shown by the arrows. The shaft is inclined at 33° 30', as shown below.

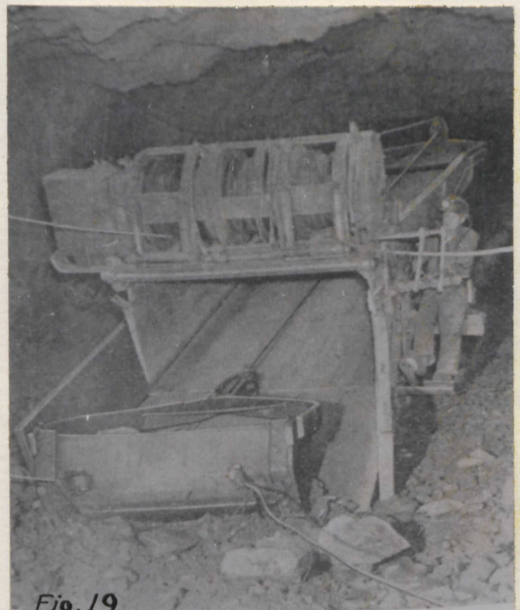

Fig. 19.

LENGTHENING SLIDE has made it possible for scraper to ascend it at angle not exceeding 40° save at lower end.

Three tracks and a manway run the entire length of the shaft. The center track and north track are used for hoisting ore in 20-tons. skips in balance. The south track is for use as a man-and-material way and is also used for handling some development muck. The center track is used for handling the shaft muck and is continually extended with temporary rails laid on the inclined rock floor on the shaft so that it is kept within about 50 ft. of the face. In this way the portable scraper slide can be kept close to the muck pile.

A round corner is left on the bottom of the shaft. Its purpose is to save time, whereas the scraper does not has to waste time scraping down into a tight corner.

The scraper weights 2,500 lbs, and the digging angle of the scraper is 55° to the direction of the pull. The scraper slide used is somewhat different to the one previously used, because it has been made longer so that the inclined approach from the shaft bottom to the point where the scraper dumps into the skip does not exceed 40°. By this change in design, scraper time was speeded up approximately 25%.

The application of this longer slide and the sequency of operations in sinking this shaft, made it possible to average a distance of 33.6 ft. per week, or 7 ft. per round.

6. Air Powered Clamshell. This unique, simple to operate machine can be used for mucking Inclined as well as Vertical Shafts. In working out the design of this machine, estudies and experiments were centered on building a rigid, precision telescoping boom that delivered a positive, pressure-controlled crowding action to the air clamshell bucket. Positive loading and pressure is thus developed at all times at the actual point of digging.

This air-operated machine, shown in Figs. 20 and 21, is powered by 7 air cylinders. It is mounted beneath the deck of a standard

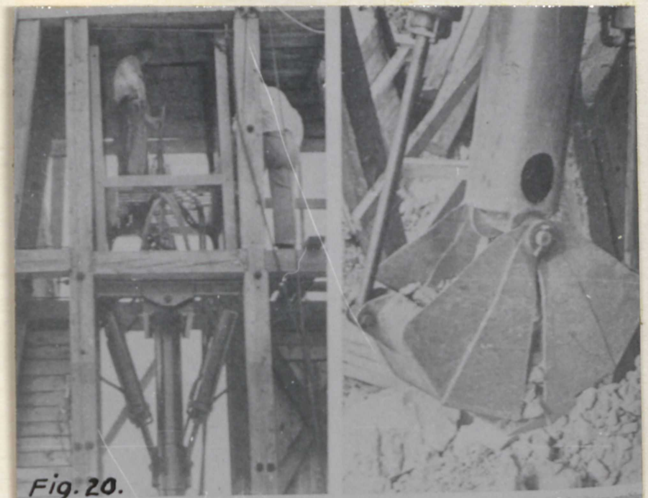

Fig. 20.

POSITIVE CONTROL of clamshell positioning and operation is obtained with two levers in the operator's cage.

POSITIVE ACTION produced by powerful air pistons enable clamshell to pick up a healthy bite of broken rock in shaft

New Positive-Action Mucking Machine

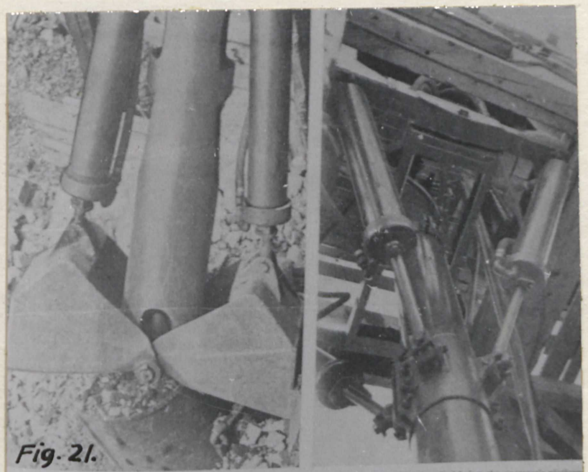

Fig. 21.

CLAMSHELL drops load in bucket. Here again positive positioning and operation of clamshell jaws is assured.

STOUT AIR PISTONS installed below the operator's platform regulate all positioning of the telescopic boom.

mine cage suspended through a gimbal-type support. The air-actuated clam is attached to the end of an air operated telescoping boom. This telescoping boom will reach in and out in any direction from the central pivot point, with direction controlled by the swing cylinders. It is possible to make any and all of these moves either separately or together through a two-lever positive control. The clamshell drops its load into a 22 ft^3. bucket, which is handled by a two-drum 75 hp. hoist. In the actual mucking operation, two buckets were in use. A fast switch-over change was used to unhook the empty bucket on delivery to the shaft bottom and to engage the loaded bucket for hoisting.

In actual timing, the buckets were loaded in 63 sec. to 67 sec. After the mucking cycle was completed, the entire unit was raised high enough to avoid damage from blasting, in less than four minutes.

7. Inclined Shaft Mucking by the Combination of Jumbo and Slusher. This unique combination drill-jumbo and slusher was designed to speed shaft-sinking at the Killingdal pyrite mine in Norway, where a 5,000 ft., 45-deg. incline shaft, 65 ft^2. in cross-section, was sunk. Although slushing in inclined shafts is not new, this unit solves the problem of filling the scraper, what as it is recognized becomes increasingly difficult as the angle increases.

Operating principle of the slusher-jumbo is as follows: The scraper is equiped with wheels which run along the main side beams of the frame. When tension is applied to the pull rope of the hoist, the scraper is carried to the frame and then raised over the skip and dumped as shown in Fig. 22. In steeper shafts,

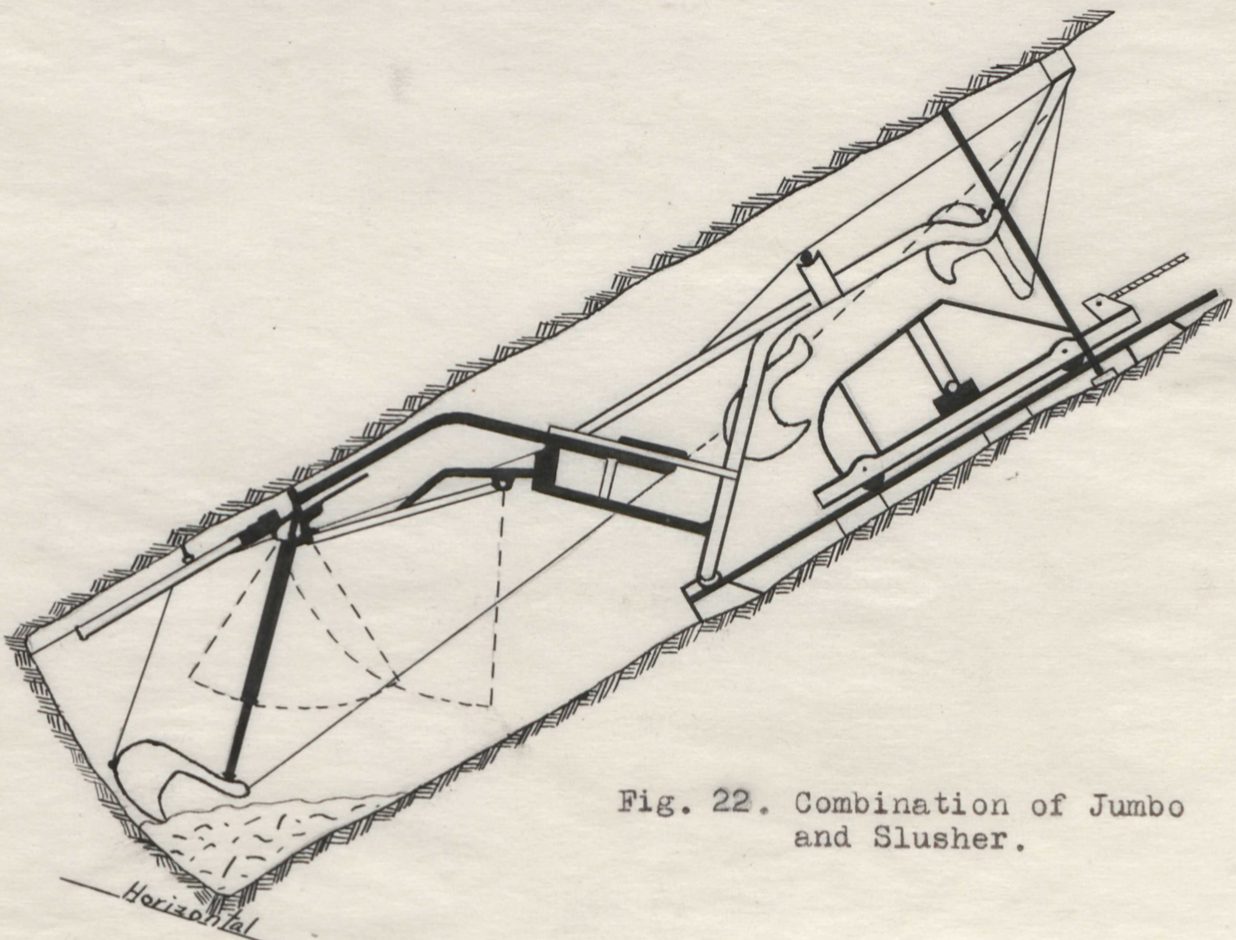

Fig. 22. Combination of Jumbo and Slusher.

a compresed air column, which swings freely in the vertical plane is used. As the scraper is pulled forward, the head of the scraper is pressed down into the muck pile to facilitate filling of the scraper. Then the air column is attached and the scraper is pulled forward along the floor until the wheels engage the side beams of the frame. Tension is maintained on the pull rope until the wheel of the scraper rests in the bend in the side arms. The pull is then slackened, and the scraper swings on the wheels to discharge its load into the skip. Thereafter the tail rope pulls the scraper back to the initial loading position at the face.

C. Looking into the Future. Bucket elevators and inclined conveyors, could doubtless be adapted to incline shaft mucking. These devices are, however, hindered by a push crowd which is somewhat inefficient. The addition of a rotorhead, thus, has been considered.

1. Rotomucker. This device is only in its model stage. It

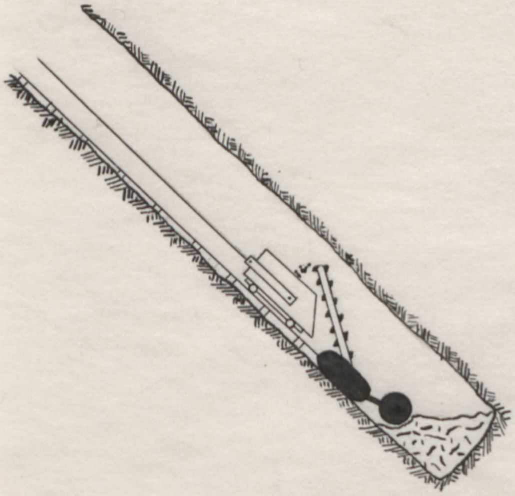

Fig. 24. Use of Rotorhead for mucking inclines.

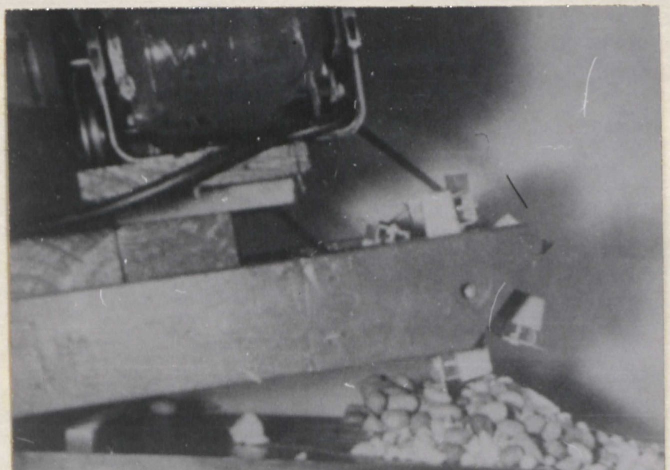

Fig. 23. Rotorhead

consists of a rotorhead, Fig. 23, which could be mounted on a crawler, wheel-rail, or tire; for the lift and feed a bucked elevator, or a conveyor and pan feeder, could be used.

Its operation is shown in Fig. 24, and it consists in mucking the shaft bottom by the use of the rotorhead. Transportation being done by a bucket elevator dumping into a skip.

This device, might, when put it into practice, prove to be feasible, resulting in further reduction in costs and an increase of speed, in mucking inclined shafts.

CONCLUSION

As being shown in this paper, several methods and devices have been used, in meeting specific requirements (as operating space, type of shaft, its size, and the kind of rock encountered) in mucking inclined shafts. However, there still is much room left for improvement of these methods, and in the ever searching path for future designs.

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